N91-24071

OPTICAL SHUTTER SWITCHING MATRIX

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VIDEO SWITCHING SYSTEMS

Requirements Overview

Data processing and peripheral support systems, ground telemetry stations, aerospace vehicles, satellites, telecommunications systems, televideo systems, and radar tracking systems are demanding improved interface and switching performance. Today's fiber optic technologies can provide tomorrow's performance systems with the bandwidth, isolation, interference immunity, signal-to-noise-ratio, flexibility, large-scale channelization, and reduction in size, weight, power, and cost.

The National Aeronautics and Space Administration is one of the many government and industry professions which relies heavily on video, data, instrumentation, communications, processors, and tracking systems to perform its mission. The interface switching system technologies needed to meet today's and tomorrow's system performance requirements must be developed and matured if large scale switching systems are to be manufactured that will meet the performance system architectures of tomorrow.

My experience with electronic switching systems is related to those used in the Space Shuttle ground control systems, transmission systems, communications systems, and airborne radar electronic countermeasure systems. My goal is to identify a need that exists throughout the comprehensive information processing and communications disciplines supporting the Space Shuttle and Space Station programs, and introduce one viable approach to satisfy that need. The proposed device is described in the NASA patent entitled, "Optical Shutter Switch Matrix."[1]

Space Shuttle Support Systems

The Kennedy Space Center comprises vast numbers of information and communication systems. The Shuttle Launch Processing System (LPS) is only one of the Center's support systems. The system is made up of three major subsystems. The first is the Control, Checkout and Monitor Subsystem (CCMS) which is the ground support station used to process and launch the Space Shuttle. The second is the Central Data Subsystem (CDS), which provides large-scale data base management for hardware and software configurations, video simulation interface, and real-time data interface used to validate the ground station software. The third is the Record and Playback Subsystem (RPS), which is the ground telemetry station used to record, play back, and analyze ground support equipment and vehicle systems status by evaluating processed and unprocessed information.[2]

The LPS alone supports some 250 engineering work stations, 350 minicomputers, 2 ADP mainframes, 27 computer simulation systems, and over 2,000 peripheral equipment systems comprising magnetic disk, analog and digital tape units, printers, plotters, and graphic recorders. These systems are interfaced through tens of thousands of copper cables, hundreds of patch panels, numerous analog and digital switching systems, and transmission-line conditioning equipment. Together they form the system used to configure, control, test, monitor and record information to and from ground support equipment, and prepare the Space Shuttle for launch. Each console work station contains varying configurations of selectable networks of nonsecure and secure interfaces for multichannel analog and digital voice communications, multichannel operational television, visual displays, and telephones. The local communications centers distribute the secure and nonsecure voice, video, and data to the Centers Satellite Tracking and Data Network and The Air Force Eastern Test Range. The information is then time division multiplexed to NASA, DoD, and Commercial

satellite communication networks to other NASA Centers, government agencies, and contractor support organizations.

Shuttle Configuration Requirements

Each Shuttle Vehicle goes through three processing facilities to prepare it for launch. The CCMS firing rooms, CDS, and RPS have to be capable of flexible configurations to support the processing of each Shuttle vehicle in any of the processing facilities. In 1983 the systems were enhanced to support DoD Payload and Shuttle vehicles. The Launch Control Center was equipped with two additional Secure CCMS firing rooms, a Secure CDS, and Secure RPS. The two Orbiter Processing Facilities (OPF), two Vertical Assembly Building (VAB) bays, and two Launch Pads were also modified to support either secure or nonsecure interfaces.

The TEMPEST engineering requirements mandated that extensive modifications be performed to prevent the compromise of information from the existing facilities and interfaces. The existing NASA cabling interfaces, switching systems and communications interfaces could not meet those requirements. Protected cable plant, separate interface cables, large quantities of manual patch panels, and distributed voice, video and data encryption devices were incorporated. The automated switching systems, originally installed to support NASA, and civilian missions, were complemented with optical couplers and manual patch panels to meet the isolation requirements. The total reconfiguration time takes 8-12 hours to configure and validate the 600-700 manual patches required to configure a ground station to support a DoD mission. Large-scale automated switching systems and the technologies needed to develop them were not, and are not, presently available.

In-place Switching Systems

The large-scale switching systems at KSC are based largely on obsolete reed relay technology, TTL Logic, MOS analog switches and amplifiers, digital multiplexers, and logic arrays. Each of these technologies exhibits many of the same inherent electronic design shortcomings. Limited information bandwidth, custom transmission-line conditioning equipment, transmission quality and error-rate considerations, impedance transformations, matching, and long-line equalization, crosstalk, finite input/output isolation, and mutual EMI/EMP/RFI interference are the same concerns still confronting designers. The 200 by 100 and 100 by 100 Remote Control Video Switching systems used in the CCMS are transformer-coupled, three-stage, latching reed relay, cross-bar switches, with operational amplifiers band limited from 2kHz to 2MHz. Each system is enclosed in five standard sized RETMA racks. Rates above or below these frequencies must bypass the switching system and be interfaced through patch panels. Non-zero crossover data types must be converted to a Manchester biphase-L format or connected directly to the equipment through patch panels.

The Remote Control Switching systems in the CDS are designed with digital logic and matching interface circuitry. Switching systems found in the communication systems are designed around MOS analog switches and digital multiplexers with matching input/output interface circuitry. The replacement switching systems being designed today for the next generation CDS are being designed around programmable logic arrays. The improved configurability and signal-to-noise-ratio gained from using this technique is being offset by the 9U board size to accommodate component counts.

Tomorrow's System Requirements

The Center's video, data, instrumentation, communications, processing, and tracking systems at KSC are all near or past their useful design life. System performance, capacity saturation, upgrade limitations, and technology and component obsolescence are the key issues confronting the agency in seeking replacement systems. The goal is to develop design concepts with a 30-year architectural design life. The equipment technologies would be retrofitted as future technology advancements become available.

KSC replacement systems are currently going through their requirements definition, concept design, or initial replacement phases. The users' performance requirements for the replacement systems are driving the next generation systems to the state of the art in optical communication technologies. The success of meeting

the requirements will depend on the commercial availability of the technology, maturity, unit cost, installation cost, operations and maintenance costs, upgradability, reliability, and their ability to withstand stress, vibration, and environmental conditions.

OPTICAL SWITCHING SYSTEMS

Requirements Overview

The magnitude, complexity, and problems being experienced in the day-to-day configuration operation of the manual and remote system interfaces supporting multiple commercial and classified missions stimulated the idea for the Optical Shutter Switch Matrix. The daily configurations and system validations of the ground stations are labor-intensive, time-consuming, and prone to error. The major obstacle in automating the configuration process was the requirement to maintain 100 dB isolation between the secure and nonsecure interfaces.

The next-generation information and communication systems for the Space Shuttle and Space Station will use global distributed networks of optical fiber. The communication interfaces being considered include Fiber Distributed Data Interface (FDDI), Broadband Integrated Services Digital Networks (BISDN), and analog and digital Fiber Optic Terminal Equipped transmission lines.

Optical Technology Transition At KSC

The major task for the design agency is to interface the new system architecture into the old system while maintaining compatibility and without impact to the program. Most of the existing facility cable plant was installed in the mid 1960's. No new copper cable plant is being installed. Some fiber optic cables have been installed to free up the existing copper cable plant to meet requirements for the old system. The fiber cable plant that has been activated is being used mainly for TDMA voice communications. The Center's Design organization proposes the complete replacement of the copper cable plant with optical fiber by the mid 1990's. The knowledge and experience with optical transmission systems must be attained quickly to support the major changes which are going to take place at the Kennedy Space Center beginning in 1991. The initial deliveries of systems for the ground stations is scheduled to begin in early 1993. The commercial development and production of optical switching technologies to support the manufacture of large-scale, high performance switching systems needs to be completed by that time.

Optical Switching Concepts

The concept of switching optic-to-optic mediums is not new. Several concepts are available that switch arrays of coupled electro-optic transmitters and receivers, switch optical fibers through mechanical devices, or distribute the optical light waves through directional control mechanisms. The performance of these concepts could exhibit limitations in size, weight, power, switching speeds, reliability, repeatability, expandability, high loss, poor resistance to shock, or high development and manufacturing costs.

Optical Shutter Switch Matrix Patent Number 4,910,396

The need for a multichannel switching technology which met the input-to-output and channel-to-channel isolation requirements, and which would not compromise the integration of both secure and nonsecure information in the same system, prompted the concept for the optical Shutter Switch Matrix. This is the first optical switching concept which combines both mature and newly developed optic technologies into a simple, small, low-power, light-weight, low-cost manufacturing package. The input and output fiber is optically fused to shutter windows mounted in optical glass wafers (Figure 1). The matrix of optical shutter cells are interfaced between a series of orthogonal nontranmissive quartz wafers containing the split and summed optical channels (Figure 3). The individual input channels are power split into a switchable matrix of optical shutter cells, with individual output fiber channels that are power summed. The individual optical shutter cells are controlled by computer addressing (Figure 2). Any input can be switched to any output by electronic or

optic activation of the transmissive optical shutter cell (Figure 4). The channel-to-channel isolation is provided in the individual optical wafer, while the input-to-output isolation is dependent on the numb of series shutter matrices incorporated in the package.[1] The device concept is conducive to both single and multimode fiber applications. Switching speeds are limited only by the speed limitations of the types of optical shutter cells employed. Liquid Crystal and Kerr type cells were identified in the initial application because of their maturity, reliability, repeatability, resistance to shock, and reasonable cost.

In June 1989 a Phase I Feasibility Study contract for the Optical Shutter Switch Matrix was awarded to E-TEK Dynamics Inc., in San Jose, California. The study was successfully completed in March 1990. The first 6 by 6 prototype device was manufactured and tested by E-TEK Dynamics to identify any manufacturing limitations, and establish preliminary performance benchmarks. The Phase II Development procurement is planned for early FY-91. An optical switching technology could be ready for production and commercially available to manufacture large-scale switching systems to support the next generation information processing and communications system by 1993.

Phase I Technical Overview

Channel Capacity:	6 by 6 tested 500 by 500 possible
Channel Bandwidth:	$\leq$ 30 GHz
Spectral Bandwidth:	(LC Shutter) 0.6 to 2 micron 2-14 micron possible
Extinction Ratio:	23.1 dB avg. $\pm$ 0.85 dB .30 dB possible
Insertion Loss:	$\leq$ 5dB
Switching Speed:	(LC Shutters) $<$120 microsec (others tested) 10 microsec to 0.01 nanosec, picosec possible
Features:	Low cost Fabrication simplicity Large spectral bandwidth Large dynamic range Extremely high electro-optic coef. High isolation Excellent expandability Excellent cascadability Excellent repeatability Small size, weight and low power Parallel switching attainable Electronically controlled
Applications:	Large scale optical switches Optical isolators Optical attenuators Optical modulators Optical multiplexers Tunable filters Optical bus interface Network switches for: FDDI, ISDN, FTTH, LAN, WAN, MAN[3]

REFERENCES

1. United States Patent: Grove, C. H.: Optical Shutter Switch Matrix, Patent Number 4,910,396, Dated March 20, 1990.

2. NASA Document: Launch Processing System Description Launch Processing System Division, Kennedy Space Center, November 26, 1984.

3. Final Technical Report: E-TEK Dynamics Inc., optical Shutter Switch Matrix (Phase I) San Jose, California, NASA Contract: NAS10-11550, June 1989 to March 1990.

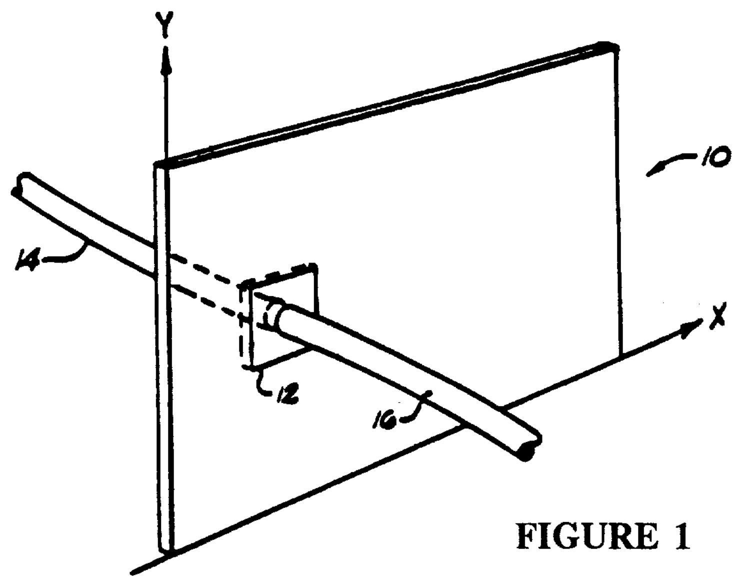

FIGURE 1

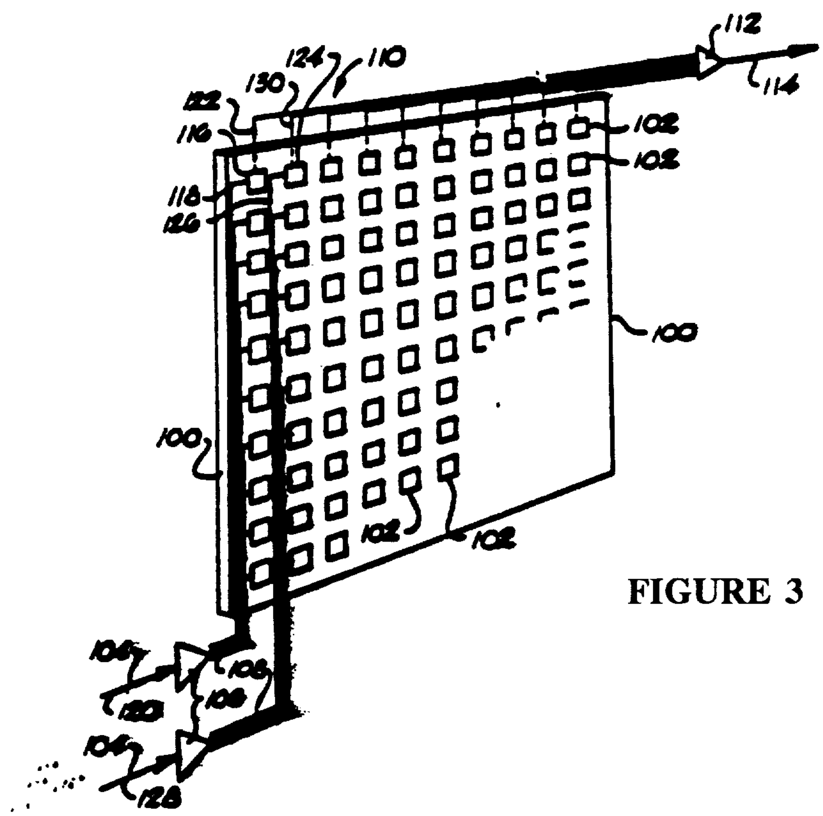

FIGURE 3

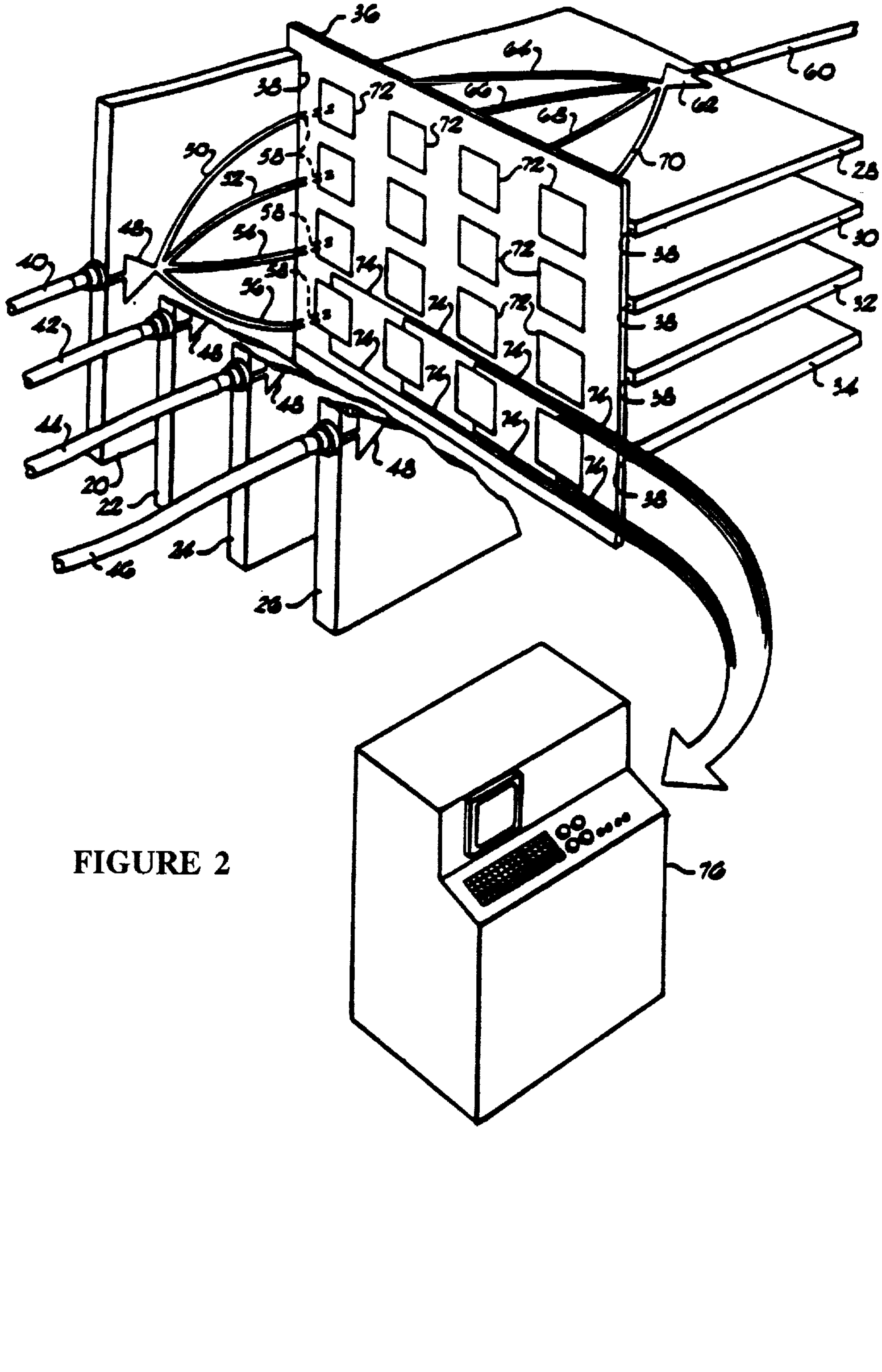

FIGURE 2

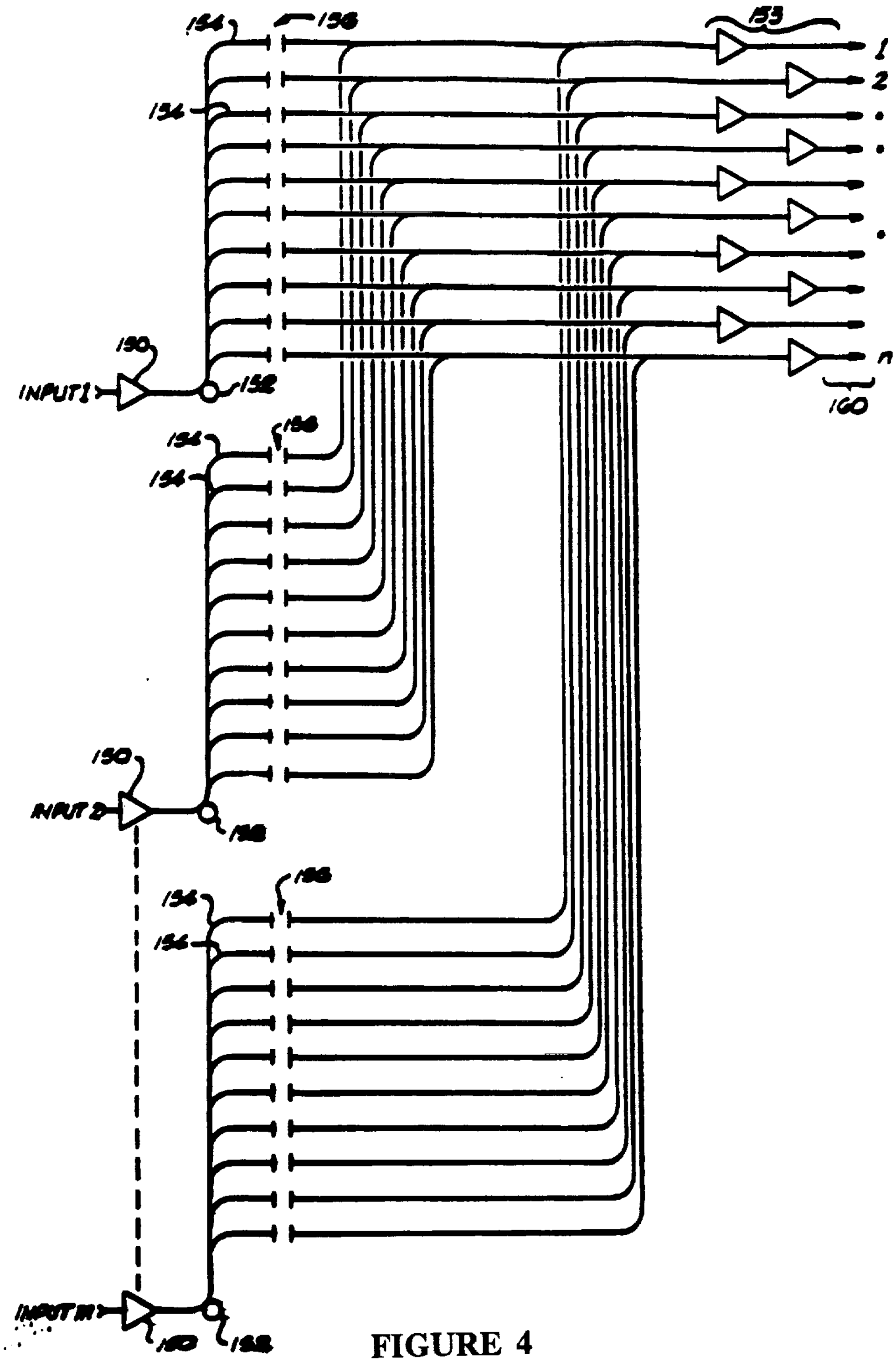
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FIGURE 4